IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

REQUEST FOR FILING
(RULE 53(b)(1))

For Design or Utility Applications

Rule 53(b)(1) PATENT APPLICATION: **(DO NOT USE FOR CIPs)**

☒ Continuation)
) application under 37 CFR 1.53(b)(1)
☐ Divisional)
application under 37 CFR 1.53(b)(1)
of pending prior application of

Group Art Unit: ______________

Examiner: ______________

Inventor(s): AALTO

Appln. No.: 08 | 849,711
Series Code ⇧ | **Serial No. ⇧**

Atty. Dkt. PM 258574 | 42887/2951671USA/bru
New M# | **Client Ref**

Filed: June 12, 1997

Title: INCREASING THE CAPACITY OF A CELLULAR RADIO NETWORK

Date: January 10, 2000

Asst. Commissioner of Patents and Trademarks
Washington, DC 20231

(Parent Matter No. 238752)

Sir:

To effect the above-requested filing today:

1. **Attached** is a copy **(which must be filed)** of the prior application, including:

☒ Abstract
☒ Specification and claims (27 pages) **(must be attached)**
☒ Drawings **(must be attached if originally filed):** 6 sheet(s)/set: ☐ 1 set informal;
☒ Formal of size ☒ A4 ☐ 11"

1A. Always X one box, only:
(1) ☒ Signed declaration or oath as originally filed in prior application attached
(2) ☐ NO declaration or fee is enclosed; therefore, this is a filing under Rule 53(f).

2. ☐ This application is hereby filed by less than all of the inventors named in the prior application. Petition is hereby made requesting deletion as inventor(s) of the following who is/are **not** inventor(s) of the invention being claimed in this application:

1. ______	2. ______
3. ______	4. ______
5. ______	6. ______
7. ______	8. ______
9. ______	10. ______

3. The entire disclosure of the prior application is considered as being part of the disclosure of the accompanying application and is hereby incorporated therein by reference thereto.

4. ☒ Priority is claimed under 35 U.S.C. 119/365 based on filing in Finland (country) of

	Application No.	Filing Date		Application No.	Filing Date
(1)	954879	Oct 13, 1995	(4)		
(2)			(5)		
(3)			(6)		

a. ☐ ______ (No.) Certified copy/copies attached.
b. ☒ Certified copy/copies previously filed on Jun 12, 1997 in U.S. Application No. 08 / 849,711, filed on Jun 12, 1997.
series code ⇧ ⇧ serial no.
c. ☐ Certified copy/copies filed during International stage of PCT/ / .

4. (a) ☒ Domestic priority is claimed from PCT/ FI96/00540 , filed 11 October 1996.
(b) ☐ Benefit is claimed of Provisional Application No. 06/___ , filed ___ .

5. ☒ Prior application is assigned to Nokia Telecommunications Oy

by assignment recorded June 12, 1997 (Date) Reel 8685 Frame 0921.

6. ☒ Attached is the following number of Assignments (including original and all later successive ones by different assignors): 1 and respective **new** Cover Sheets. (Do **NOT** file old cover sheets.)

(Assignments in parent **must be refiled** with new Cover Sheets in this continuing application if you want it/them recorded against the continuing application.)

Please return the recorded Assignment to the undersigned.

7. ☒ The power of attorney in the prior application is to Pillsbury Madison & Sutro, LLP, Dale S. Lazar, 28872
(Name and Reg. No.)
whose current address is as in item 8 below.

a. ☒ Recognize as associate attorney Brian Siritzky, Reg. No. 37,497 and Heather Morin, Reg. No. 37,336
(Name, Reg. No. and Address)

8. **Address all future communications to Intellectual Property Group of Pillsbury Madison & Sutro LLP, Ninth Floor, East Tower 1100 New York Avenue, N.W., Washington, D.C. 20005-3918**

9. ☒ **Amend the specification** by inserting before the first line the sentence:--This is a ☒ continuation ☐ division of Application No. 08/849,711, filed June 12, 1997
series code ⇧ ⇧ serial no.
which is the national phase of international application PCT/FI96/00540, filed October 11, 1996 which designated the U.S. .--

9. (a) ☐ **Amend the specification** by inserting before the first line: --This application claims the benefit of Provisional Application No. 60/___, filed ___ .--

10. ☐ It has been recently determined that this new continuing application is entitled to small entity status. Hence:
__(No.) Verified Statement(s) establishing "small entity" status under Rules 9 & 27 were/are:
☐ filed in above prior application (and hence applicable hereto)
☐ attached.

11. Petition to extend the life of the above prior application to at least the date hereof
(one box) ☐ is being concurrently filed in that prior application (Use Form PAT-111).
(must be) ☐ was previously filed in that prior application (Check length of prior extension).
(X'd) ☒ is not necessary for copendency (**Double check** before X'ing this box).

12. ☒ **INFORMATION DISCLOSURE STATEMENT:** Attached is Form PTO-1449 listing all of the documents cited by Applicant and the PTO in the parent application(s) relied upon under 35 USC 120 and referenced in item 9 above. Per Rule 98(d) copies of those documents are not required now. Please consider those documents and advise that they have been considered in this new application as by returning a copy of the enclosed Form PTO-1449 with the Examiner's initials in the left column per MPEP 609. .

13. ☐ Attached is a Rule 103(a) Petition to Suspend Action.

14. ☒ **PRELIMINARY AMENDMENT to be entered before fee calculation:** (Do not make amendments here except for correction of improper multiple dependencies or cancellation of whole claims or multiple dependencies for purpose of reducing the filing fee per MPEP §§ 506 and 607; do not cancel all claims).

Claim 5, lines, 1 and 2, change "any one of the preceding claims" to --claim 1--; Claim 7, line 1, delete "or Claim 6"; Claim 11, line 1, delete "or Claim 10"; Claim 12, line 1, delete "10 or 11,"; and Claim 14, line 1, delete "or Claim 13".

FILING FEE

THE FOLLOWING FILING FEE IS BASED ON

->->->->CLAIMS AS FILED AND **CHANGED BY PRELIMINARY AMENDMENT IN ITEM 14**<-<-<-<-

NOTE: If box 1A2 is X'd, do not pay fees, but leave lines 15-22 and 27-32 blank.

				Large/Small Entity		Fee Code
15. Basic Filing Fee ....Design Application				$310/$155		106/26
16. Basic Filing Fee .... Not Design Application				$690/$345	+690	101/201
17. Total Effective Claims	15	minus 20 =	0	x $18/$9	+0	103/203
18. Independent Claims	2	minus 3 =	0	x $78/$39	+0	102/202
19. If any proper multiple dependent claim (ignore improper) is present,				$260/$130	+0	104/204
20.				**Subtotal =**	**$690**	
21. If "petition" box 13 above is X'd, add petition fee...............$130					+0	122
21A. If box 6 above is X'd, add Assignment recording fee ....$ 40					+40	581

22. **TOTAL FILING FEE ATTACHED = $730**

(carry forward to Item 31)

23. ☐ ATTACHED:

24. ☒ Preliminary Amendment attached (to be entered after assigning Appln. No.)

25. ☐ The following PRELIMINARY AMENDMENT is to be entered after assigning Appln. No.:

26. **ADDITIONAL FEE CALCULATION FOR PRELIMINARY AMENDMENT PER BOXES 24/25**

	Claims remaining after amendment		Highest number previously paid for		Present Extra		Large/Small Entity		Additional Fee	File Code
27. Total Effective Claims	*15	minus **	20	=		x	$18/$9	=	$ 0	(103/203)
28. Independent Claims	*2	minus ***	3	=		x	$78/$39	=	+ 0	(102/202)

29. If amendment enters proper multiple dependent claim(s) into this application for the first time, add (per application) . . . . $260/$130 + 0 (104/204)

30. ADDITIONAL FEE $ ______

31. plus **FEE** from item 22 on page 3 + 730

32. **TOTAL FEE ATTACHED** $ 730

33. *If the entry in this space is less than a entry in the next space, the "Present Extra" result is "0"

34. **If the "Highest number previously paid for" (see item 17 above) is less than 20, write "20" in this space

35. If the "Highest number previously paid for" (see item 18 above) is less than 3, write "3" in this space

Our Deposit Account No. 03-3975

Our Order No.	60258	258574
	C#	M#

CHARGE STATEMENT: Upon the filing of a Declaration pursuant to Rule 60(b) or 60(d), the Commissioner is hereby authorized to charge any fee specifically authorized hereafter, or any missing or insufficient fee(s) filed, or asserted to be filed, or which should have been filed herewith or concerning any paper filed hereafter, and which may be required under Rules 16-18 (missing or insufficient fee only) now or hereafter relative to this application and the resulting Official document under Rule 20, or credit any overpayment, to our Account/Order Nos. shown above for which purpose a duplicate copy of this sheet is attached.

This CHARGE STATEMENT does not authorize charge of the issue fee until/unless an issue fee transmittal form is filed.

Pillsbury Madison & Sutro LLP
Intellectual Property Group

1100 New York Avenue, NW
Ninth Floor
Washington, DC 20005-3918
Tel: (202) 861-3000
BS/HM:lap
Atty./Sec.

By Atty: Brian Siritzky **Reg. No.** 37497

Sig: ______ **Fax:** (202) 822-0944
Tel: (202) 861-3702

NOTE No. 1: File this Request in duplicate with 2 postcard receipts (PAT-103) & attachments
NOTE No. 2: Is extension in parent necessary for copendency? **DOUBLE CHECK** Item 11 above.

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re PATENT APPLICATION of

AALTO Group Art Unit: ____

CONTINUATION of Appln. No.: 08/849,711 Examiner: ________

Filed: June 12, 1997

FOR: INCREASING THE CAPACITY OF A CELLULAR RADIO NETWORK

* * * * *

January 10, 2000

PRELIMINARY AMENDMENT

Hon. Commissioner of Patents
and Trademarks
Washington, D.C. 20231

Sir:

Prior to consideration of this application on its merits, please enter the following amendments:

IN THE SPECIFICATION:

Page 1, after line 1, on a new line, insert --FIELD OF THE INVENTION--;

after line 3, on a new line, insert --BACKGROUND OF THE INVENTION--;

line 8, after "reuse", insert a semicolon --;--;

line 16, after "hand", insert a comma --,--; and change "increase" to --increases--;

lines 16-17, delete "on the other hand";

line 28, after "networks", insert a comma --,--;

line 29, after "hopping", insert a comma --,--; and

line 32, change "through" to --by--.

Page 2, line 4, change "localised" to --localized--; and

line 6, delete "the"; and change "installations" to --installation--.

Page 3, line 8, after "i.e.", insert a comma --,--;

line 10, after "e.g.", insert a comma --,--;

line 11, after "e.g.", insert a comma --,--;

after line 24, insert on a new line, --SUMMARY OF THE INVENTION--;

line 30, after "network", insert --in--; and delete "in accordance with the invention is characterized by";

line 31, delete "said"; and change "being" to --are--; and

line 34, change the comma "," to a period --.--.

Page 4, line 1, change "at" to --At--; and change "having" to --have--;

line 2, delete the comma ","; and delete "said";

line 3, delete "said";

line 5, change the comma "," to a period --.--;

line 6, after "controlling", insert --or a controller which controls--; and delete "said";

line 7, delete "said"; and delete "means of";

line 11, change "comprises the steps of:" to --includes--;

line 19, after the comma ",", insert --and--;

line 20, delete "said";

line 21, delete "said"; and delete "means of";

line 26, delete "means of"; and

line 27, change "in such a way" to --so--.

Page 5, line 2, change "neighbouring" to --neighboring--;

line 7, after "hence", insert a comma --,--;

line 8, after "is" and "example", insert a comma --,--;

line 14, delete "means of";

line 15, delete "mans of"; and

line 32, change "On the basis of" to --Based on--.

Page 6, line 3, change "the primary" to --a first--;

line 18, change "primary" to --first--;

after line 28, on a new line, insert --BRIEF DESCRIPTION OF THE DRAWINGS--; and

line 31, after "illustrates", insert --a--.

Page 7, line 9, after the comma ",", insert --and--;

after line 11, on a new line, insert --DETAILED DESCRIPTION OF THE CURRENTLY PREFERRED EMBODIMENT OF THE INVENTION--; and

line 34, change "centre" to --center--.

Page 8, line 17, after "i.e.", insert a comma --,--;

line 18, after “example”, insert a comma --,--;

line 20, after “H”, insert a comma --,--;

line 28, after “e.g.”, insert a comma --,--;

line 30, after “e.g.”, insert a comma--,--; and

line 31, after “e.g.” insert a comma --,--.

Page 9, line 27, change “MSC; in” to --MSC. In--;

line 31, change “neighbouring” to --neighboring--; and

lines 34, change “neighbouring” to --neighboring--;

Page 10, line 1, change “bouring” to --boring--; and change “i.e.” to --i.e.,--;

line 7, change “neighbouring” to --neighboring--;

line 10, change “i.e.” to --i.e.,--; and

line 28, change “i.e.” to --i.e.,--; and after “H”, insert a comma --,--.

Page 11, line 1, change “neighbouring” to --neighboring--;

line 3, change “e.g.” to --e.g.,--; and

line 10, after “S2”, insert a comma --,--.

Page 12, line 1, change “i.e.” to --i.e.,--;

line 2, change “i.e.” to --i.e.,--;

line 5, change “the primary” to --a first--;

line 20, change “e.g.” to --e.g.,--;

line 23, change “e.g.” to --e.g.,--;

line 28, change "i.e." to --i.e.,--; and

line 35, after "Thus", insert a comma --,--.

Page 15, line 19, change "neighbouring" to --neighboring--;

line 23, change "neighbouring" to --neighboring--; and change "primary" to --first--;

line 29, change "neighbouring" to --neighboring--;

line 30, change "neighbouring" to --neighboring--; and

line 34, change "neighbouring" to --neighboring--.

Page 16, line 9, change "neighbouring" to --neighboring--.

Page 17, line 4, delete "means of".

Page 19, line 28, delete "means of".

Page 22, line 10, change "recognises" to --recognizes--.

IN THE CLAIMS:

Please amend claims 1-15 as follows:

1. (Amended) A cellular radio network [comprising] including allocated radio frequencies reused in cells, [characterized by] comprising:

said allocated radio frequencies being divided into regular radio frequencies for which lower frequency reuse is utilized to achieve a seamless overall coverage, and super-reuse frequencies to which high frequency reuse is applied to provide a high traffic carrying capacity[,];

at least some of [the] said cells having both at least one regular frequency and at least one super-reuse frequency, so that said at least one regular frequency is intended to serve primarily in cell boundary regions and said at least one super-reuse frequency is intended to serve primary in the vicinity of [the] a base station[,]; and

[means controlling] a controller which controls traffic load distribution in [the] a cell between said at least one regular and said at least one super-reuse frequency by [means of] intra-cell handovers induced by estimated interference on said at least one super-reuse frequency.

2. (Amended) [A] The cellular radio network as claimed in [Claim] claim 1, [characterized in that

the cause of] wherein a handover from a regular frequency to a super-reuse frequency [is] occurs at a [sufficiently good] predetermined interference level on [the] said super-reuse frequency, and

[the cause of] wherein a handover from a super-reuse frequency to a regular frequency [is] occurs when there is too poor an interference level on [the] said super-reuse frequency.

3. (Amended) [A] The system as claimed in [Claim] claim 1, [characterized in that

the] wherein a BCCH frequency of the cell is [always] a regular frequency, and wherein a [that the] radio frequency assigned in call-setup or [a] handover from another cell is [always] a regular frequency.

4. (Amended) [A] The cellular radio network as claimed in [Claim] claim 1, [characterized in that it] further [comprises] comprising:

at least one microcell having only super-reuse frequencies, one of [which is] said super-reuse frequencies being a BCCH frequency, and

[that] call set-up in [the] a microcell is barred, and [the cellular network comprises means for controlling] said controller controls traffic load distribution between regular cells and [the] said microcell by [means of] inter-cell handovers induced by [the] an interference level in [the] said microcell.

5. (Twice Amended) [A] The cellular radio network as claimed in claim 1, comprising:

a mobile-assisted handover procedure in which [the] a mobile station [(MS)] measures [the] a signal receiving level of [the] a serving cell and [the] a signal level of [the] adjacent cells and forwards [the] said measurement results to [the] said handover controller [means] of [the] said cellular network, [characterized in that the] wherein said handover controller [means is adapted to estimate the] estimates an interference level on [the] said super-reuse frequencies of [the] said serving cell based on [the basis of the] said measurement results.

6. (Amended) [A] The cellular radio network as claimed in [Claim] claim 5, [characterized in that] wherein one or more adjacent cells have been assigned to each super-reuse frequency of [the] said serving cell, [the] said measured receiving level of [the] said adjacent cell being used [for estimating the] to estimate interference on said super-reuse frequency.

7. (Twice Amended) [A] The cellular radio network as claimed in [Claim] claim 5, [characterized in that the] wherein said measurement results of [the] said mobile station only concern a limited number of ambient cells, and that at least one reference cell has been assigned to at least one super-reuse frequency of [the] said serving cell from among said ambient cells, said reference cell having an interference profile of a [similar] type [as] similar to an interference profile of a more remote cell which is a potential source of interference on [the] said super-reuse frequency but cannot be directly measured by [the] said mobile station, and that [the] said handover controller [means is adapted to estimate the level of] estimates said interference level caused by said more remote cell on [the] said super-reuse frequency, using [the] said measured signal level of [the] said reference cell.

8. (Amended) [A] The cellular radio network as claimed in [Claim] claim 7, [characterized in that the] wherein a handover algorithm is adapted to estimate [the] a signal level of [the] an interfering cell by correcting [the] said measured receiving level of [the] said reference cell taking into account [the] a difference in [the] signal levels of [the] said reference cell and [the] an actual interfering cell.

9. (Amended) A method for increasing traffic carrying capacity in a cellular radio system, [characterized in that it comprises the steps of] comprising:

dividing [the] radio frequencies of [the] said cellular radio network into regular radio frequencies for which lower frequency reuse is utilized to achieve seamless overall coverage, and super-reuse frequencies to which higher frequency reuse is applied to provide a high traffic carrying capacity[,];

allocating to at least some [of the] cells of said cellular radio network both at least one regular frequency and at least one super-reuse frequency so that [the] said regular frequency is intended to serve primarily in cell boundary regions and [the] said super-reuse frequency is intended to serve [primarily] in [the] a vicinity of [the] a base station[,]; and

controlling traffic load distribution in [the] a cell between said at least one regular and said at least one super-reuse frequency by [means of] intra-cell handovers induced by estimated interference on said at least one super-reuse frequency.

10. (Amended) [A] The method as claimed in [Claim] claim 9, [characterized by] further comprising:

performing an intra-cell handover from a regular frequency to a super-reuse frequency when [the] said super-reuse frequency has a [sufficiently good] predetermined interference level[,]; and

performing a handover from a super-reuse frequency to a regular frequency when [the] said super-reuse frequency has too poor an interference level.

11. (Twice Amended) [A] The method as claimed in [Claim] claim 9, [characterized by] further comprising:

allocating a regular frequency as [the] a BCCH frequency of [the] said cell in each case[,]; and

assigning a regular frequency in call set-up or in a handover from another cell in each case.

12. (Twice Amended) [A] The method as claimed in [Claim] claim 9, [characterized by] further comprising:

measuring [the] a signal receiving level[, preferably also the] and quality[,] of [the] a serving cell at [the] said mobile station[,];

measuring [the] said signal receiving level of [the] cells ambient to [the] said serving cell at [the] said mobile station[,];

forwarding [the] measurement results from [the] said mobile station to [the] said cellular radio network[,]; and

estimating [the] an interference level on [the] said super-reuse frequencies of said [the] serving cell based on [the basis of the] said measurement results.

13. (Amended) [A] The method as claimed in [Claim] claim 12, [characterized by] further comprising:

assigning one or more adjacent cells to each super-reuse frequency of [the] said serving cell, [the] said measured receiving level of the adjacent cell being used [for estimating the] to estimate said interference level on said super-reuse frequency.

14. (Twice Amended) [A] The method as claimed in [Claim] claim 12, [characterized by

the] wherein said measurement results reported by [the] said mobile station only [concerning] concern a limited number of ambient cells,

said method further comprising:

assigning at least one reference cell to at least one super-reuse frequency of [the] said serving cell from among said ambient cells, said reference cell having an interference profile of a [similar] type [as] similar to an interference profile of a more remote cell which is a potential source of interference on [the] said super-reuse frequency but cannot be directly measured by [the] said mobile station[,]; and

estimating [the level of] an interference level caused by said more remote cell on [the] said super-reuse frequency[,] using [the] said measured signal level of [the] said reference cell.

15. (Amended) [A] The method as claimed in [Claim] claim 14, [characterized by] further comprising:

correcting [the] said measured signal level of [the] said reference cell taking into account [the] a difference in [the] signal levels of [the] said reference cell and said remote cell in [the estimation of the] estimating said interference level.

REMARKS

Favorable reconsideration of this application in view of the above amendments and the following remarks is respectfully requested. In this amendment, claims 1-15 have been amended to more clearly present the claimed invention. Unless otherwise specifically stated, claims 1-15 have been amended to address Section 112, second paragraph, issues, noted by the Applicant, and for no other reason.. Applicant submits no new matter has been added, and notice to that effect is respectfully requested. Currently, claims 1-15 are pending.

Applicant respectfully submits that all pending claims are in condition for allowance, and early action indicating formal notice of such is solicited.

Respectfully submitted,

PILLSBURY MADISON & SUTRO LLP

By for No 37336

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APPLICATION UNDER UNITED STATES PATENT LAWS

Invention: INCREASING THE CAPACITY OF A CELLULAR RADIO NETWORK

Inventor(s): AALTO, Risto

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This is a:

[ ] Provisional Application

[ ] Regular Utility Application

[ ] Continuing Application

[XX] PCT National Phase Application

[ ] Design Application

[ ] Reissue Application

[ ] Plant Application

SPECIFICATION

INCREASING THE CAPACITY OF A CELLULAR RADIO NETWORK

The present invention relates to cellular radio networks and particularly to methods for increasing the capacity of a cellular radio network.

The most significant factor reducing the capacity of radio systems is the limited frequency spectrum available. The capacity of a radio system is thus dependent on how efficiently the radio frequencies allocated to the system can be utilized. In cellular radio networks, enhanced utilization of radio frequencies is based on frequency reuse: the same frequency is reused at several locations that are sufficiently spaced apart, which affords a vast increase in system capacity. This is counteracted by increased complexity in the network as well as in the mobile units which must be capable of selecting a base station from among several possible base stations. For example, if the same frequency is reused in every ninth cell, the spectral allocation of N frequencies permits the use of N/9 carriers simultaneously in any cell. Diminishing the cell size or reducing the distance between cells using the same frequency will enhance capacity on the one hand but also increase co-channel interference on the other hand. Therefore, selection of the reuse factor is often a compromise between co-channel interference and the traffic carrying capacity of the system.

Since the frequency spectrum allocated to a cellular radio network is fixed and the number of subscribers is rapidly increasing, efficient use of the allocated frequency spectrum is vital to any network operator. Hence, various features increasing the traffic carrying capacity in the cellular network will provide much-needed relief to operators, particularly in crowded urban areas. Radio network evolution towards high-capacity radio networks has the following main alternatives: increasing the number of channels, splitting the cells (small cells), microcellular networks, multi-layered networks, underlay-overlay networks and other capacity enhancement concepts, such as half-rate channels, frequency hopping and power control. In the following, these alternatives will be described in more detail.

INCREASING THE NUMBER OF CHANNELS

The simplest way to supplement capacity is through increasing the number of channels. Since the allocated cellular spectrum per network operator is very limited, this method does not give relief from capacity problems.

SPLITTING CELLS (SMALL CELLS)

When cell sizes are reduced below a radius of 1 km, there generally is a need to lower the antenna height below rooftop level. This is because coverage to localised areas at street level cannot be efficiently engineered from a rooftop installation. Such lowering of antennas causes problems in designing the coverage. Prediction of ranges for these types of installations is less well understood than in cases of macrocells. Furthermore, interference management becomes more difficult from below rooftop installations, as overspill into co-channel base stations cannot be equally controlled. Cell overspill may eventually reduce cell sizes to the point where conventional planning practices and radio systems do not work efficiently. Additionally, any significant capacity enhancement is accompanied by major investments in BTS sites and transmission connections. Splitting of cells is a good method for capacity relief up to a certain point. Unfortunately, urban area capacity requirements are so high that this method does not offer help in the long run. Cell splitting can therefore only be used for short term relief.

MICROCELLULAR NETWORK

There is no exact definition of "microcellular network". A cell having a small coverage area and antennas below rooftop level could be the characteristics in the definition of a "microcell". Microcellular concepts are often mistakenly referred to as "multi-tiered", but a "microcell" can be deployed without a multi-layer architecture. In implementing cell splitting below a certain limit and placing antennas below rooftop level or in buildings, advanced solution radio network planning and radio resource control is needed. An increased number of BTS sites significantly increases the costs. For cells with a radius of 300 m - 1 km, signal variability due to shadow fading is very high compared to macrocells and relative to the coverage area of the small cells. These factors mean that cell overlaps need to be very high in order to meet the desired overall coverage; this is, of course, inefficient. Cells with a radius below 300 m experience more line of sight signal propagation and somewhat less signal variability, which is helpful from a coverage point of view. However, antenna location in these circumstances very significantly determines the actual coverage area. Localized blockages which cause serious shadows effectively produce coverage holes. Small antenna location variations significantly alter the effectiveness and characteristics of the BTS site. There are two alternative solutions to

these problems: to deploy more cells accepting the inefficiency of high cell overlap, or significantly increase and improve engineering effort in the actual BTS site selection and planning process. Both of these solutions increase the costs to the operator. The net result is that a microcellular network does not give a significant capacity increase without major investment in BTS sites and transmission connections.

UNDERLAY-OVERLAY NETWORK

To cope with the two conflicting goals in radio network design, i.e. coverage and capacity, it is possible to build a radio network which has two (or more) separate cell layers, one, e.g. a macrocell layer, providing overall coverage and the other, e.g. a microcell layer, providing capacity. The "coverage layer" uses a conventional frequency reuse pattern and cell range to provide seamless overall coverage. The "capacity layer" uses a very tight frequency reuse pattern and a shorter cell range to achieve high capacity with a few channels. Multi-layered networks are often also referred to as "underlay-overlay" networks.

In an underlay-overlay network, there are many ways to control the handover between layers. The handover decision can be made on the basis of field strength or power budget values. In this case, the interference level must be predefined for each BTS site and the handover thresholds and transmit power are adjusted to minimise the interference. The interference control is always a statistical method and the resulting average quality is therefore not a quality guarantee for a single connection. For this reason, the achieved increase in capacity is questionable.

It is an object of the present invention to improve frequency utilization in an underlay-overlay cellular radio network without increase in co-channel interference, and thereby to significantly improve capacity without any major additional investments or extensive modifications to the network.

This and other objects of the invention will be achieved with a cellular radio network which in accordance with the invention is characterized by

said allocated radio frequencies being divided into regular radio frequencies for which lower frequency reuse is utilized to achieve a seamless overall coverage, and super-reuse frequencies to which high frequency reuse is applied to provide a high traffic carrying capacity,

at least some of the cells having both at least one regular frequency and at least one super-reuse frequency, so that said at least one regular frequency is intended to serve primarily in cell boundary regions and said at least one super-reuse frequency is intended to serve primarily in the vicinity of the base station,

means controlling traffic load distribution in the cell between said at least one regular and said at least one super-reuse frequency by means of intra-cell handovers induced by estimated interference on said at least one super-reuse frequency.

The invention also relates to a method for increasing traffic carrying capacity in a cellular radio system. The method comprises the steps of:

dividing the radio frequencies of the cellular radio network into regular radio frequencies for which lower frequency reuse is utilized to achieve seamless overall coverage, and super-reuse frequencies to which higher frequency reuse is applied to provide a high traffic carrying capacity,

allocating to at least some of the cells both at least one regular frequency and at least one super-reuse frequency so that the regular frequency is intended to serve primarily in cell boundary regions and the super-reuse frequency is intended to serve primarily in the vicinity of the base station,

controlling traffic load distribution in the cell between said at least one regular and said at least one super-reuse frequency by means of intra-cell handovers induced by estimated interference on said at least one super-reuse frequency.

In the invention, the operating frequency spectrum of the cellular network is divided into regular frequencies and super-reuse frequencies. By means of these two sets of frequencies, two or more separate network layers are provided, at least locally, in the cellular radio network in such a way that typically both regular frequencies and super-reuse frequencies are employed in each cell.

One layer, the 'overlay layer', utilizes regular frequencies and a conventional frequency reuse pattern and cell coverage to achieve seamless overall coverage. Frequency planning for regular frequency reuse is made by conventional criteria using safe handover margins and requiring low co-channel and adjacent channel interference probabilities. Regular frequencies are intended to serve mobile stations mainly at cell boundary areas and other locations where the co-channel interference ratio is poor. The overlay network

also provides interference-free service in the overlapping cell areas required for handover control and neighbouring cell measurements by mobile stations.

Another layer (or several other layers), the 'underlay layer', is composed of super-reuse frequencies. The underlay network employs a very tight frequency reuse pattern to provide extended capacity. This is based on the fact that in the underlay network the same frequency is reused more often than in the overlay network, and hence more transceivers can be allocated within the same bandwidth. If the frequency reuse is for example twice as tight as originally, the number of transceivers can be doubled. The super-reuse frequencies are intended to serve mobile stations which are close to the BTS, inside buildings and at other locations where the radio conditions are less vulnerable to interference.

The cellular network controls traffic division into regular and super-reuse frequencies by means of radio resource allocation at the call set-up phase and later on during the call by means of handover procedures. The capacity increase actually provided by such an underlay-overlay network is essentially dependent on how efficiently the mobile stations can be directed to use the super-reuse frequencies and how well call quality deterioration resulting from co-channel interference caused by an increased level of frequency reuse can be avoided.

In accordance with the invention, this problem is solved by directly and dynamically controlling the co-channel interference level of each specific call. The radio network estimates the degree of interference on different frequencies and directs the mobile stations to those frequencies that are sufficiently "clean" of interference to sustain a good radio connection quality. More precisely, the cellular network continuously monitors the downlink co-channel interference of each super-reuse frequency in the cell individually for each ongoing call. The call is handed over from a regular frequency to a super-reuse frequency when the co-channel interference level on the super-reuse frequency is sufficiently good. When the co-channel interference level on the super-reuse frequency deteriorates, the call is handed over from the super-reuse frequency back to a regular frequency. On the basis of the profile of interference each mobile is exposed to, the cellular network determines the most appropriate frequency for the call connection. The use of measured co-

channel interference level as a handover decision criterion guarantees that the same interference requirements are met for any single cell.

In the primary embodiment of the invention, the cell is provided with both regular and super-reuse frequencies, so that the BCCH frequency of the cell is one of the regular frequencies, whereas the super-reuse frequency is never a BCCH frequency. Call set-up and handover from another cell is always first carried out to a regular frequency in the cell, whereafter an underlay-overlay handover in accordance with the invention to a super-reuse frequency of the cell may be performed.

Stand-alone microcells may be configured solely to use the super-reuse frequencies. Such a microcell is termed a child cell herein. By establishing appropriate handover connections, a child cell at a good location, i.e. a traffic hot spot, can handle more traffic than a regular cell in its vicinity. A child cell is an independent cell having a super-reuse frequency as its BCCH frequency. Traffic is conveyed to the child cell by means of a handover, since call set-up to the child cell is not possible (only super-reuse frequencies, the interference level cannot be measured prior to call set-up).

In the primary embodiment of the invention, the co-channel interference level is estimated by comparing the downlink signal level of the serving cell and the downlink signal levels of those neighbouring cells which use the same super-reuse frequencies as the serving cell. The radio network can calculate the estimated co-channel interference level at the location of each active mobile station. The calculation of the co-channel interference is based on the measurement results on the BCCH frequencies of the mobile station, which the mobile station measures also for a normal handover and reports to the cellular network. In fact, one of the advantages of the invention is that it does not require any modifications to mobile stations in conventional cellular networks.

The invention will be explained in the following by means of preferred embodiments with reference to the accompanying drawing, in which

Figure 1 illustrates part of a cellular radio system in which the invention can be applied,

Figure 2 illustrates a conventional cellular radio network employing one frequency reuse pattern,

Figure 3 illustrates a cellular network in accordance with the invention, employing regular and super-reuse frequencies,

Figure 4 illustrates underlay and overlay layers provided by the super-reuse frequencies and regular frequencies respectively in the network of Figure 3,

Figure 5 represents a schematic block diagram of a base station in accordance with the invention,

Figure 6 represents a schematic block diagram of a base station controller in accordance with the invention,

Figure 7 illustrates base station-specific and transceiver-specific parameters set in the database of the base station controller.

The present invention can be applied to all cellular radio systems.

The present invention is particularly suited to cellular systems employing mobile-assisted cellularly controlled handover, such as the pan-European digital mobile communication system GSM (Global System for Mobile Communications) and in other GSM-based systems, such as DCS 1800 (Digital Communication System), and in the U.S. digital cellular system PCS (Personal Communication System). The invention will be described in the following by using the GSM mobile communication system as an example. The structure and operation of the GSM system are well known to those skilled in the art and are defined in the GSM specifications of ETSI (European Telecommunications Standards Institute). Furthermore, reference is made to M. Mouly & M. Pautet, *GSM System for Mobile Communication*, Palaiseau, France, 1992; ISBN: 2-9507190-0-7.

The general structure of a GSM-type cellular network is illustrated in Figure 1. The network is composed of two parts: a Base Station Subsystem BSS and a Network Subsystem (NSS). The BSS and mobile stations MS communicate via radio links. In the base station subsystem BSS, each cell is served by a base station BTS. A number of base stations are connected to a base station controller BSC, the function of which is to control the radio frequencies and channels employed by the BTS. The tasks of the BSC also include handovers in cases where the handover is performed within the BTS or between two BTSs both of which are controlled by the same BSC. The BSCs are connected to a mobile services switching centre MSC. Certain MSCs are

connected to other telecommunications networks, such as the public switched telephone network PSTN, and comprise gateway functions for calls to and from such networks. Such MSCs are known as gateway MSCs (GMSC).

For clarity, Figure 1 shows only one MSC and one base station subsystem in which nine base stations BTS1-BTS9 are connected to a base station controller BSC, the radio areas of the base stations constituting respective radio cells C1-C9.

1.0 CONVENTIONAL CELLULAR NETWORK

The cellular network can be drawn as a combination of circles or hexagons, such as cells C1-C9 in Figure 1. A hexagonal cell is quite different from the actual world, but is still a good way of approximating the network. The cells may have different configurations, such as omni, bisectoral, trisectoral, etc.

The basic principle of a cellular network is frequency reuse, in other words, the same frequency is reused in cells with a given spacing. Reuse is usually represented by a frequency reuse pattern, composed of a cluster of cells using different frequencies. Cluster size, i.e. the number of cells in a cluster, is often used as a yardstick for the reuse factor. For example in Figure 2, the reuse pattern or cluster 20 comprises 9 cells using mutually different frequencies or sets of frequencies A, B, C, D, E, F, G, H and I. The same frequencies are reused in clusters of the same size throughout the cellular network. The cluster size, cell size and spacing between two cells using the same frequency are determined by the desired C/I (carrier-to-interference) ratio, which is the ratio of the desired receiving signal level to the received interference signal. The most significant interference is usually co-channel interference from another cell using the same frequency. This causes the planning problem stated in connection with the description of the prior art: Enhancement of frequency reuse, e.g. reducing cell size, increases the traffic carrying capacity but also the co-channel interference. One prior art solution is a multilayer network having a "coverage layer" provided by one cell layer, e.g. macrocell network, and a "capacity layer" provided by one cell layer, e.g. microcell network. However, forming of the other cell layer requires considerable investment and modifications to the network. Furthermore, handover control between the layers has been based on the field strength or power budget, and

thus the connection quality and capacity increase achieved in the cellular network are questionable, as explained above in connection with the prior art.

1.1. Conventional handover

As is well known, mobile stations MS can roam freely within the area of the mobile communication system from one cell to another. Handover is only re-registration with another cell when the mobile station does not have any ongoing call. When the mobile station MS has an ongoing call during the handover, also the call must be connected from one base station to another in a way least disturbing to the call. Transfer of a call from a traffic channel to another traffic channel of the same cell or another cell during a call is termed a handover.

Handover decisions are made by the base station controller BSC on the basis of the different handover parameters set for each cell and on the measurement results reported by the mobile station MS and the base stations BTS. Handover is normally induced on the basis of the criteria for the radio path, but handover may also be due to other reasons, including load distribution. The procedures and calculation on the basis of which the handover decision is made are called a handover algorithm.

For example in accordance with the technical recommendations for the GSM system, the mobile station MS monitors (measures) the downlink signal level and quality of the serving cell and the downlink signal level of the cells surrounding the serving cell. The MS is capable of measuring 32 cells at most and reporting the measurement results of the six best BTS to the BSC. The BTS monitors (measures) the uplink signal level and quality, received from each mobile station MS served by said base station BTS. All measurement results are forwarded to the BSC. Alternatively, all handover decisions can be made in the MSC; in that case, the measurement results are forwarded to the MSC as well. The MSC also controls at least those handovers that are made from the area of one BSC to the area of another BSC.

When the MS roams in the radio network, handover from the serving cell to a neighbouring cell is normally effected either when (1) the measurement results of the MS and/or BTS show a low signal level and/or signal quality for the downlink signal of the currently serving cell and a better signal level is to be obtained from a neighbouring cell, or when (2) one of the neigh-

bouring cells permits communication at lower transmit power levels, i.e. when the MS is located in the boundary region of cells. In radio networks, unnecessarily high power levels and thereby interference to other parts of the network are avoided as far as possible. The BSC selects, on the basis of the handover algorithm employed in the system and the reported measurement results, the neighbouring cells whose radio path has properties sufficient for a possible handover. These selected neighbouring cells are called handover candidate cells in this context, and the final target cell for handover is selected from these. At its simplest, the selection of the target cell may be effected by selecting a candidate cell having the best radio path properties, i.e. the best signal level. The candidate cells may, however, be ranked according to specific priority levels on other grounds as well.

2.0 UNDERLAY-OVERLAY NETWORK IN ACCORDANCE WITH THE INVENTION

In the invention, the operating frequency spectrum of the cellular network is divided into regular frequencies and super-reuse frequencies. By means of these two sets of frequencies, two or more separate "network layers" are provided, at least locally, in the cellular radio network in such a way that typically both regular frequencies and super-reuse frequencies, to which mutually different reuse factors are applied, are employed in each cell. An exception is made by a child cell, which will be described in detail below. Figure 3 illustrates a cellular network in accordance with the invention, which has been formed by adding super-reuse frequencies into the cells of the conventional cellular network of Figure 2. Figure 4 illustrates how the regular and super-reuse frequencies in the cells form two separate "network layers" in the frequency domain.

One layer 41, the 'overlay layer', utilizes the regular frequencies of cells 10, i.e. A, B, C, D, E, G, H and I, and a conventional frequency re-use pattern and cell radius to produce seamless overall coverage. Frequency planning for regular frequency reuse is made by conventional criteria using safe handover margins and requiring low co-channel and adjacent channel interference probabilities. Regular frequencies are intended to serve mobile stations mainly at cell boundary areas and other locations where the co-channel interference ratio is poor. The overlay network also provides interference-free service in the overlapping cell areas required for handover control and

neighbouring cell measurements by a mobile station. Hence, an overlay network is typically a conventional cellular radio network. It may also be a cell layer in a network comprising two physical cell layers, e.g. a macrocell, microcell or picocell layer. In such a case, the frequency spectrum division in accordance with the invention is carried out within the physical macrocells, microcells or picocells. In the example of Figures 3 and 4, the overlay network is a unidimensional cellular network in accordance with Figure 2 in which the cluster size is 8.

Another layer (or several other layers) 42, the 'underlay layer', is composed of the super-reuse frequencies S1, S2 and S3 of the cells. It is thus to be noted that the invention typically employs only one physical cell layer and that the overlay and underlay layers are not made up by different physical cells by different frequencies or sets of frequencies in the same physical cell. The underlay network employs a very tight frequency reuse pattern, so that a smaller coverage, represented by a small hexagon 11 in Figure 3, is created for the super-reuse frequencies within regular cell 10. Provision of extended capacity is based on the fact that in the underlay network the same frequency can be reused more often than in the overlay network, and hence more transceivers can be allocated within the same bandwidth. In the example of Figures 3 and 4, the cluster size of the underlay layer is 3, and thus the number of transceivers per frequency can be nearly tripled compared with the overlay layer (cluster size 8). The super-reuse frequencies are intended to serve mobile stations which are close to the BTS, inside buildings and at other locations where the radio conditions are less vulnerable to interference. As illustrated in Figures 3 and 4, the super-reuse frequencies do not provide continuous coverage but rather form separate islands. However, it is possible, depending on the frequency reuse factor, that also the super-reuse frequency coverages overlap.

A cellular network may employ several sets of super-reuse frequencies to which similar or different reuse is applied independently. Each set of super-reuse frequencies thus forms a distinct underlay "network layer".

Division of cell frequencies into regular and super-reuse frequencies is controlled transceiver-specifically at the base station BTS. All radio transceivers (TRX) at the BTS are defined either as regular TRXs or super-reuse TRXs (a child cell is an exception). The radio frequency of a regular TRX is

among the regular frequencies, i.e. A-I. The radio frequency of a super-reuse TRX is one of the super-reuse frequencies, i.e. S1, S2 and S3. Each BTS must additionally have a 'broadcast control channel frequency' (BCCH frequency) which is measured by the MS in adjacent cell measurements, for example. In the primary embodiment of the invention, the BCCH frequency is always one of the regular frequencies. A child cell again makes an exception; therein the BCCH frequency is a super-reuse frequency.

The base station BTS of cell 10 is typically furnished with both types of TRX. Figure 5 illustrates a BTS in accordance with the invention, comprising two TRXs 51 and 52. It is to be noted, however, that there may be any desired number of TRXs. TRX 51 is a regular TRX whose radio frequency A is one of the regular frequencies and also provides the BCCH frequency for the cell. TRX 52 is a super-reuse TRX whose radio frequency S1 is one of the super-reuse frequencies. TRXs 51 and 52 are connected via a combiner and divider unit 54 to common transmitting and receiving antennas ANT_{TX} and ANT_{RX}. Regular and super-reuse frequencies may also have separate antennas, for instance to obtain as advantageous a coverage as possible for the super-reuse frequencies. TRXs 51 and 52 are further connected to transmission system equipment 55 providing connection to a transmission link to the BSC, e.g. a 2 Mbit/s PCM link. The operation of the TRXs 51 and 52 is controlled by controller unit 53 having a signalling connection with the BSC through the transmission system equipment 55. The BTS in accordance with the invention may be a fully commercial base station, e.g. GSM Base Station DE21 by Nokia Telecommunications Oy. What is essential to the invention is the division of the frequencies used by the TRXs.

An exception to the cell and base station principle presented above is a 'child cell'. A child cell is an individual physical microcell having a suitable location, i.e. a traffic hot spot, and configured to use super-reuse frequencies only. In other words, in view of frequency spectrum division, the child cell is located on one of the underlay layers and is capable of handling more traffic than a regular cell in its vicinity by establishing appropriate handover connections. Since a child cell is an independent cell, it employs a super-reuse frequency as its BCCH frequency. For a child cell, however, in the primary embodiment of the invention a barring parameter preventing call set-up directly to the child cell is sent on the BCCH frequency. Thus a child cell can only be

reached by handover from an adjacent regular cell, which is termed a parent cell. Figure 4 shows a child cell 44 having a super-reuse frequency S4.

The cellular network, in the primary embodiment of the invention a BSC, controls traffic division into regular and super-reuse frequencies by means of radio resource allocation at the call set-up phase and later on during the call by means of handover procedures. Figure 6 shows a schematic block diagram of a BSC. A group switch GSW 61 provides the connection operation of the BSC. Besides routing calls between the base stations BTS and the MSC, the group switch GSW is employed to connect calls in intra-BSC handovers. Controller unit 62 handles all control operations within the base station subsystem BSS, such as the execution of handover algorithms. Network configuration database 63 contains all handover and configuration parameters of the base station subsystem BSS. All parameters required by the underlay-overlay feature in accordance with the invention are stored in the database 63. One of the base station-specific and TRX-specific parameter settings included in the database 63 is depicted in Figure 7; herein TRX-specific parameters define, for instance, whether a regular or a super-reuse TRX is concerned. The other parameters will be described in detail below. The present invention only requires the modifications to be more closely described below to the functions of the controller unit 62 and to the parameter settings in the database 63. Otherwise the BSC of the invention can be implemented with any commercial BSC.

3.0 INTELLIGENT UNDERLAY-OVERLAY HANDOVER

3.1 General principle

The capacity increase practically provided by the underlay-overlay network of the invention is dependent on how efficiently the mobile stations MS can be directed to use the super-reuse frequencies and how well call quality deterioration is simultaneously avoided.

In the invention, the BSC controls traffic division into regular and super-reuse frequencies by means of radio resource allocation at the call set-up phase and later on during the call by means of a handover. The BSC allocates a traffic channel to the call to be set up or to a call handed over from another regular cell at a regular TRX only, wherefore a regular cell must have at least one regular TRX, typically a BCCH TRX, as illustrated in Figure 5. After

this, the BSC monitors the downlink C/I ratio on each super-reuse frequency of the regular cell separately for each ongoing call. The monitoring is accomplished in such a way that the BSC calculates the downlink C/I ratio of the super-reuse TRX by means of various parameters and by means of measurement results reported by the MS via the BTS. The principle of the C/I evaluation is simple. By comparing the downlink signal level of the serving cell (C= Carrier) and the downlink signal levels of the neighbouring cells (I = Interference) which use the same super-reuse frequencies as the serving cell, the BSC can calculate the C/I ratio on the super-reuse frequencies at the location of each active mobile station MS. The C/I can be calculated in this way, since the downlink transmit power is the same on the regular and super-reuse frequencies of the cell.

Example: A super-reuse frequency 90 has been allocated to cells A and B, and the cells are close enough to each other to cause interference. When the downlink signal level of the serving cell A is -70 dBm and the signal level of the adjacent cell B is -86 dBm, the downlink C/I ratio of the super-reuse TRX (frequency 90) of cell A is 16 dB.

The BSC always hands the call from the regular TRX over to the super-reuse TRX when the downlink C/I ratio of the super-reuse TRX is sufficiently good (handover HO_2 in Figure 4). If the downlink C/I ratio of the super-reuse TRX becomes poor, the BSC again hands the call from the super-reuse TRX over to the regular TRX in the same cell (handover HO_3 in Figure 4). If there is also a child cell under the BSC - such as child cell 44 in Figure 4 - which is adjacent to the regular/serving cell, the BSC continuously monitors the downlink C/I ratio of each super-reuse frequency of the child cell during each call. The call is handed over from the regular cell to the child cell when the downlink C/I ratio of the child cell is sufficiently good (handover HO_5 in Figure 4). If the downlink C/I ratio of the child cell becomes poor, the call is handed over from the child cell to one regular/parent cell adjacent to the child cell (handover HO_6 in Figure 4).

The above-described radio resource allocation and handovers together form an intelligent underlay-overlay feature in the cellular network; this feature is controlled by means of various parameters as illustrated in Figure 7. These required parameters are stored in the network configuration database 63 at the BSC (Figure 6). The network operator can administer the

parameters for example through the operations and maintenance centre OMC of the network. The underlay-overlay feature in accordance with the invention has special requirements for every stage of the handover algorithm: processing of measurement results, threshold comparison and decision algorithm. Nevertheless, the intelligent underlay-overlay feature in accordance with the invention is still compatible with the above-described standard handover algorithm. This is due to the fact that the BSC uses different handover decision algorithms for handovers arising from traffic control between regular and super-reuse frequencies than for handovers arising from conventional radio path criteria, such as power budget, low signal level or poor signal quality.

In the following, the main steps of the underlay-overlay handover in accordance with the invention are described in detail, these steps being: 1) processing of radio link measurements, 2) C/I determination procedure, 3) handover threshold comparison, and 4) selection of a handover candidate.

3.2 Processing of radio link measurements

As stated previously, underlay-overlay handover decisions made by the BSC are based on measurement results reported by the MS and on various parameters. Database 63 at the BSC is capable of maintaining a measurement table of 32 neighbouring cells per each call and storing the measurement results as they arrive. Furthermore, a specific number of interfering cells has been defined for each super-reuse TRX, as illustrated in Figure 7. The interfering cells must be adjacent to the serving cell, as the MS only measures cells defined in the list of neighbouring cells. In the primary embodiment of the invention, for the BSC to be able to monitor several super-reuse TRXs and cells interfering with them simultaneously for one call, it must be possible to define five interfering cells at most to each super-reuse TRX. This enables simultaneous monitoring of all super-reuse TRXs at the BSC.

The information on the cells being measured is sent to the MS in a neighbouring cell list. The MS measures the cells defined in the list and reports the measurement results of the six strongest neighbouring cells to the BSC. The interfering cells must be adjacent to the serving cell, otherwise the MS is not capable of measuring and reporting the signal levels of the interfering cells. In any case, the measurement results of the interfering cells are often weaker than those of the six strongest neighbouring cells, wherefore the

measured downlink level RXLEV of the interfering cell is available only intermittently.

When the RXLEV of the interfering cell is missing from the measurement results, the steps to be taken vary depending on whether the RXLEV of the interfering cell is considered as a directly measured interference level or whether the RXLEV of the interfering cell is a reference value which is used for calculating an interference level estimate, as will be explained in item 3.3.

1) Directly measured interference level. When the MS reports the measurement results of the six neighbouring cells, that is, the six positions in the measurement sample are occupied, the weakest RXLEV of the six reported cells is entered as the measurement value for those interfering cells that are missing from the measurement sample. When the MS reports the measurement results of less than six neighbouring cells, a zero is entered as the measurement value for those interfering cells that are missing from the measurement sample.

2) The measurement value is used for calculating an interference level estimate. For those cells whose measurement values are used for calculating an interference level estimate and are missing from the measurement sample, a zero is entered as the measurement value.

In order for the result to have maximum reliability, the BSC can calculate an average of several measurement results, which is then used in the C/I evaluation.

3.3. C/I evaluation

C/I evaluation is carried out each time the BSC receives measurement results and an average of these is calculated.

If the call is on a regular TRX, the C/I evaluation concerns every super-reuse TRX of the serving cell and those child cells which are adjacent to the serving cell. In such a case, the evaluation strives to find a super-reuse TRX having a sufficiently good C/I ratio for handover.

If the call has been handed over to a super-reuse TRX, the C/I evaluation concerns only the super-reuse TRX itself. In such a case, the purpose of the evaluation is to monitor whether the C/I ratio of the super-reuse

frequency is good enough or whether the call is to be handed over to a regular frequency.

The BSC calculates the downlink C/I ratio of the super-reuse TRX in the manner set out above by means of the processed measurement results (averages) and the parameters set for said TRX. The processed measurement results are the downlink RXLEV of the serving cell, the downlink RXLEV of the interfering cells and the downlink RXLEV of the child cell. The parameters are Level Adjustment, CIEstWeight and CIEstType; these are set for the TRX in database BSC (Figure 7). Level Adjustment is the adjustment level of the interfering cell (-63 dB...63 dB), which is used to calculate an interference level estimate from the signal level of the interfering cell. CIEstWeight is the weighting coefficient of the interfering cell (1...10). CIEstType indicates whether the signal level of the interfering cell is considered as a directly measured interference level or whether the signal level of the interfering cell is a reference value which is used for calculating an interference level estimate.

By comparing the downlink RXLEV of the super-reuse TRX and the downlink interference level, the BSC can calculate the C/I ratio of the super-reuse TRX.

3.3.1. Calculation of the RXLEV of the super-reuse TRX

For the above comparison, the RXLEV of the super-reuse TRX must first be determined.

In the following, cases in which the super-reuse TRX is allocated to a regular cell (case 1) or to a child cell (cases 2 and 3) are considered.

1) The average downlink receiving level AV_RXLEV_TRX(k) of the super-reuse TRX of a regular cell is calculated in the following way:

(AV_RXLEV-TRX(k)=AV_RXLEV_DL_HO+(BS-TXPWR_MAX-BS_TXPWR) (1)

where AV_RXLEV_DL_HO is the average downlink RXLEV of the serving cell. BS_TXBWR__MAX-BS_TXBWR is the difference between the maximum downlink RF power permitted in the serving cell and the actual downlink power due to the BTS power control.

2) When the child cell is the handover candidate, the average downlink receiving level AV_RXLEV_TRX(k) of the super-reuse TRX equals the average downlink receiving level of the child cell.

3) When the child cell is the serving cell, the average downlink receiving level AV_RXLEV_TRX(k) of the super-reuse TRX is calculated in the following way:

AV_RXLEV_TRX(k)=AV_RXLEV_DL_HO+(BS_TXPWR_MAX-BS_TXPWR) (2)

3.3.2. Directly measured interference level

The most common situation is that the interfering cell is a regular cell which is adjacent to the serving cell and the interfering cell has the same set of super-reuse frequencies as the serving cell. Also the location of the interfering cell is close enough to cause interference. In this situation, the average downlink receiving level AV_RXLEV_INFx(k) of the interfering cell corresponds directly to the interference level I on the super-reuse TRX caused by the interfering cell.

3.3.4. Estimated interference level

If the call is on a super-reuse TRX (BCCH frequency) of the child cell or the child cell is a handover candidate and the potential source of interference is another child cell with the same super-reuse frequency (also BCCH frequency), the corresponding interference level cannot be directly measured and reported by the MS because of the same BCCH frequencies. In this case, the BSC can only estimate the level of interference caused by the other child cell by means of the signal levels which the MS can measure and report.

If the RF signal profile of a regular adjacent cell is similar to the interference profile within the coverage area of the serving cell, it is possible to define the regular adjacent cell as the interfering cell (reference cell) instead of the true source of interference. The RF signal profile is considered the same as the interference profile when the ratio between the RF signal level and the interference level (for example 6 dB) remains approximately unchanged within the service area of the serving cell. This ratio is represented by means of the above parameter LevelAdjustment set for each interfering or reference cell, as

illustrated in Figure 7. The type of the adjacent cell is indicated by means of the parameter CIEstType.

3.3.3.1 Interference level estimation based on several cells

In order to increase the reliability of the estimation, several reference cells may be used for calculating the estimated downlink interference level AV_RXLEV_ESTM(k). AV_RXLEV_ESTM(k) and the downlink C/I ratio of the super-reuse TRX are calculated by using similar evaluation methods. Various mathematical methods, such as the average taking method and the maximum taking method, can be used to calculate the downlink C/I ratio of the super-reuse TRX or the estimated downlink interference level. A cellular network may employ several calculation methods, which are selected for instance cell-specifically by means of special parameters. The average taking method will be described by way of example in the following.

Average taking method

The estimated downlink interference level AV_RXLEV_ESTM(k) is calculated by means of the average taking method in the following way (when only the RXLEVs of the reference cells are taken into account):

AV_RXLEV_ESTM(k) =

[W1(k) * (AV_RXLEV_INTF1(k) + LEV_ADJ_INTF1(k)) +
W2(k) * (AV_RXLEV_INTF2(k) + LEV_ADJ_INTF2(k))]/ (3)

[W1(k) + W2(k) + W3(k) + W4(k) + W5(k)]

The downlink C/I ratio CI_RATIO(k) of the super-reuse transceiver TRX(k) is calculated by means of the average taking method in the following way (when only the RXLEVs of the interfering cells are taken into account; instead of the RXLEVs of the reference cells, the downlink interference level AV_RXLEV_ESTM(k) estimated by means of equation 3 is used):

CI_RATIO(k) =

[W3(k)*(AV_RXLEV_TRX(k)-AV_RXLEV_INTF3(k)-LEV_ADJ_INTF3(k))+
W4(k)*(AV_RXLEV_TRX(k)-AV_RXLEV_INTF4(k)-LEV_ADJ_INTF4(k))]+,
1*(AV_RXLEV_TRX(k)-AV_RXLEV_ESTM(k))]/

(W3(k) + W 4(k) + 1) (4)

LEV_ADJ_INFTx(k) is the adjustment parameter (LevelAdjustment) of the interfering/reference cell and Vx(k) is the weighting coefficient of the interfering/reference cell (parameter CIEstWeight, set for each interfering cell).

3.4. Handover threshold comparison

The underlay-overlay feature in accordance with the invention introduces two special handover thresholds in addition to the normal handover thresholds:

- SuperReuseGoodCiThreshold is a threshold used in the comparison of the downlink C/I ratio of the super-reuse TRX to initiate a handover to the super-reuse TRX.

- SuperReuseBadCiThreshold is a threshold used in the comparison of the downlink C/I ratio of the super-reuse TRX to initiate a handover away from the super-reuse TRX. Both handover thresholds are composed of three parts: the actual threshold (CiRatio), the total number of comparisons (Nx) to be taken into account before a decision is possible, the number of comparisons out of total comparisons (Px) where the downlink C/I ratio has to be lower/greater than or equal to the threshold before any measures are possible. Each time the PSC receives measurement results from MS1 (e.g. after each SACCH multiframe), the BSC compares the downlink C/I ratio of specified super-reuse TRXs with a specified handover threshold. When the call is on a regular TRX, the threshold comparison concerns every super-reuse TRX of the serving cell and those child cells which are adjacent to the serving cell, and the handover threshold is SuperReuseGoodCiThreshold. If the call has been handed over to a super-reuse TRX, the threshold comparison concerns only the super-reuse TRX itself and the handover threshold is SuperReuseBadCiThreshold.

The threshold comparison and the steps to be taken are as follows:

1) Comparison of the downlink C/I ratio CI_RATIO(k) with SuperReuseGoodCiThreshold. If at least in Bx comparison out of the total Nx comparisons the downlink C/I ratio of the super-reuse TRX, CI_RATIO(k), is greater than or equal to the threshold CiRatio, a handover from a regular TRX to a super-reuse TRX(k) can be made on account of the good C/I ratio.

2) Comparison of the downlink C/I ratio CI_RATIO(k) with SuperReuseBadCiThreshold. If at least in Bx comparison out of the total Nx comparisons the downlink C/I ratio of the super-reuse TRX, CI_RATIO(k), is lower than or equal to the threshold CiRatio, a handover from a super-reuse TRX(k) to a regular TRX is required on account of the bad C/I ratio.

3.5. Handover decision algorithms

3.5.1. Intra-cell handover from a regular TRX to a super-reuse TRX

The BSC recognises the possibility to make a handover when the handover threshold comparison indicates that a handover, the cause of which is a good C/I ratio, can be made from a regular TRX to a specified super-reuse TRX. If there are several super-reuse TRXs in the serving cell which meet the handover requirements for the C/I ratio simultaneously, the handover algorithm ranks the super-reuse TRXs according to the C/I ratios. If there is an appropriate super-reuse TRX in the serving cell and in the child cell at the same time, the BSC prefers the child cell to the serving cell. In other words, the BSC performs an inter-cell handover to the child cell instead of the intra-cell handover.

3.5.2. Intra-cell handover from a super-reuse TRX to a regular TRX

The BSC recognises the necessity to make a handover when the handover threshold comparison indicates that some of the following criteria for a handover are present: downlink interference, downlink quality and bad C/I ratio. When the cause of the handover attempt is downlink interference or downlink quality and the intra-cell handover to a regular TRX fails, the BSC may perform a handover to another regular cell in order to maintain the call.

3.5.3. Intra-cell handover between super-reuse TRXs

The BSC recognises the necessity to make a handover when the handover threshold comparison indicates than an intra-cell handover, the cause of which is uplink interference, might be required. If the intra-cell handover attempt to another super-reuse TRX fails or the handover is not enabled, the BSC may perform either an intra-cell handover or an inter-cell handover to a regular TRX in order to maintain the call.

3.5.4. Inter-cell handover from a regular cell to a child cell

The BSC recognises the possibility to make a handover when the handover threshold comparison indicates that a handover, the cause of which is a good C/I ratio, could be made from a regular TRX to a specified super-reuse TRX of the child cell. In order for the handover to the child cell to become possible, the child cell must also satisfy the following requirements for the radio link properties:

1. AV_RXLEV_NCELL(n) > RXLEV_MIN(n) + MAX(0, Pa)
   where Pa = (MS_TXPWR_MAX(n) - P) (5)
2. PBGT(n) > HO_MARGIN_PBGT(n)

RXLEV_MIN(n) is the level which the signal level AV_RXLEV_NCELL(n) in the child cell (n) must exceed before the handover is possible. This parameter is set for each adjacent cell for the normal handover algorithm. MS_TXBWR_MAX(n) is the maximum RX power than an MS is permitted to use on a traffic channel in the adjacent cell. H_MARGIN_BGT(n) is the margin which the power budget PBGT(n) of the child cell (n) must exceed before the handover is possible. Also these are parameters that are set for each adjacent cell for the normal handover. B is the maximum power of the MS.

If there are appropriate super-reuse frequencies in many child cells, the BSC ranks the child cells according to priority levels and the load of the child cells and selects the best child cell to be the target cell. If there are several super-reuse TRXs in the child cell which meet the requirements for the C/I ratio simultaneously, the handover algorithm ranks the TRXs according to the C/I ratios.

3.5.5. Inter-cell handover from a child cell to a regular cell

The BSC recognises the necessity to make a handover when the handover threshold comparison indicates that some of the following criteria for a handover are present: downlink interference, downlink quality and bad C/I ratio. If there are several regular cells available, the BSC selects one regular cell which has the best signal strength condition to be the target cell. If there are no regular cells available within the area of the BSC, the BSC may initiate an inter-BSC handover caused by the conventional tradition criteria in order to maintain the call. After call set-up and after all handovers, there is preferably a given period of time during which the C/I evaluation is considered unreliable and the handover is not allowed. This period is allowed for the MS to decode the identifiers BSIC of the interfering/reference cells before the C/I evaluation is started. Furthermore, repeated handovers for the same MS are preferably prevented by setting a minimum interval between handovers related to the same connection. Furthermore, if a handover attempt fails for some reason, a new attempt to the same connection is only permitted after a minimum interval.

The figures and the description pertaining to them are only intended to illustrate the present invention. In its details, the present invention may vary within the scope and spirit of the attached claims.

Claims:

1. A cellular radio network comprising allocated radio frequencies reused in cells, characterized by

said allocated radio frequencies being divided into regular radio frequencies for which lower frequency reuse is utilized to achieve a seamless overall coverage, and super-reuse frequencies to which high frequency reuse is applied to provide a high traffic carrying capacity,

at least some of the cells having both at least one regular frequency and at least one super-reuse frequency, so that said at least one regular frequency is intended to serve primarily in cell boundary regions and said at least one super-reuse frequency is intended to serve primarily in the vicinity of the base station,

means controlling traffic load distribution in the cell between said at least one regular and said at least one super-reuse frequency by means of intra-cell handovers induced by estimated interference on said at least one super-reuse frequency.

2. A cellular radio network as claimed in Claim 1, characterized in that

the cause of a handover from a regular frequency to a super-reuse frequency is a sufficiently good interference level on the super-reuse frequency, and

the cause of a handover from a super-reuse frequency to a regular frequency is too poor an interference level on the super-reuse frequency.

3. A system as claimed in Claim 1 or Claim 2, characterized in that

the BCCH frequency of the cell is always a regular frequency, and that the radio frequency assigned in call-setup or a handover from another cell is always a regular frequency.

4. A cellular radio network as claimed in Claim 1, characterized in that it further comprises at least one microcell having only super-reuse frequencies one of which is a BCCH frequency, and that call set-up in the microcell is barred, and the cellular network comprises means for controlling traffic load distribution between regular cells and the microcell by means of inter-cell handovers induced by the interference level in the microcell.

5. A cellular radio network as claimed in any one of the preceding claims, comprising a mobile-assisted handover procedure in which the mobile station (MS) measures the signal receiving level of the serving cell and the signal level of the adjacent cells and forwards the measurement results to the handover controller means of the cellular network, characterized in that the handover controller means is adapted to estimate the interference level on the super-reuse frequencies of the serving cell on the basis of the measurement results.

6. A cellular radio network as claimed in Claim 5, characterized in that one or more adjacent cells have been assigned to each super-reuse frequency of the serving cell, the measured receiving level of the adjacent cell being used for estimating the interference on said super-reuse frequency.

7. A cellular radio network as claimed in Claim 5 or Claim 6, characterized in that the measurement results of the mobile station only concern a limited number of ambient cells, and that at least one reference cell has been assigned to at least one super-reuse frequency of the serving cell from among said ambient cells, said reference cell having an interference profile of a similar type as a more remote cell which is a potential source of interference on the super-reuse frequency but cannot be directly measured by the mobile station, and that the handover controller means is adapted to estimate the level of interference caused by said more remote cell on the super-reuse frequency, using the measured signal level of the reference cell.

8. A cellular radio network as claimed in Claim 7, characterized in that the handover algorithm is adapted to estimate the signal level of the interfering cell by correcting the measured receiving level of the reference cell taking into account the difference in the signal levels of the reference cell and the actual interfering cell.

9. A method for increasing traffic carrying capacity in a cellular radio system, characterized in that it comprises the steps of

dividing the radio frequencies of the cellular radio network into regular radio frequencies for which lower frequency reuse is utilized to achieve seamless overall coverage, and super-reuse frequencies to which higher frequency reuse is applied to provide a high traffic carrying capacity,

allocating to at least some of the cells both at least one regular frequency and at least one super-reuse frequency so that the regular frequency

is intended to serve primarily in cell boundary regions and the super-reuse frequency is intended to serve primarily in the vicinity of the base station,

controlling traffic load distribution in the cell between said at least one regular and said at least one super-reuse frequency by means of intra-cell handovers induced by estimated interference on said at least one super-reuse frequency.

10. A method as claimed in Claim 9, characterized by

performing an intra-cell handover from a regular frequency to a super-reuse frequency when the super-reuse frequency has a sufficiently good interference level, and

performing a handover from a super-reuse frequency to a regular frequency when the super-reuse frequency has too poor an interference level.

11. A method as claimed in Claim 9 or Claim 10, characterized by

allocating a regular frequency as the BCCH frequency of the cell in each case,

assigning a regular frequency in call set-up or in a handover from another cell in each case.

12. A method as claimed in Claim 9, 10 or 11, characterized by

measuring the signal receiving level, preferably also the quality, of the serving cell at the mobile station,

measuring the signal receiving level of the cells ambient to the serving cell at the mobile station,

forwarding the measurement results from the mobile station to the cellular radio network,

estimating the interference level on the super-reuse frequencies of the serving cell on the basis of the measurement results.

13. A method as claimed in Claim 12, characterized by

assigning one or more adjacent cells to each super-reuse frequency of the serving cell, the measured receiving level of the adjacent cell being used for estimating the interference level on said super-reuse frequency.

14. A method as claimed in Claim 12 or Claim 13, characterized by

the measurement results reported by the mobile station only concerning a limited number of ambient cells,

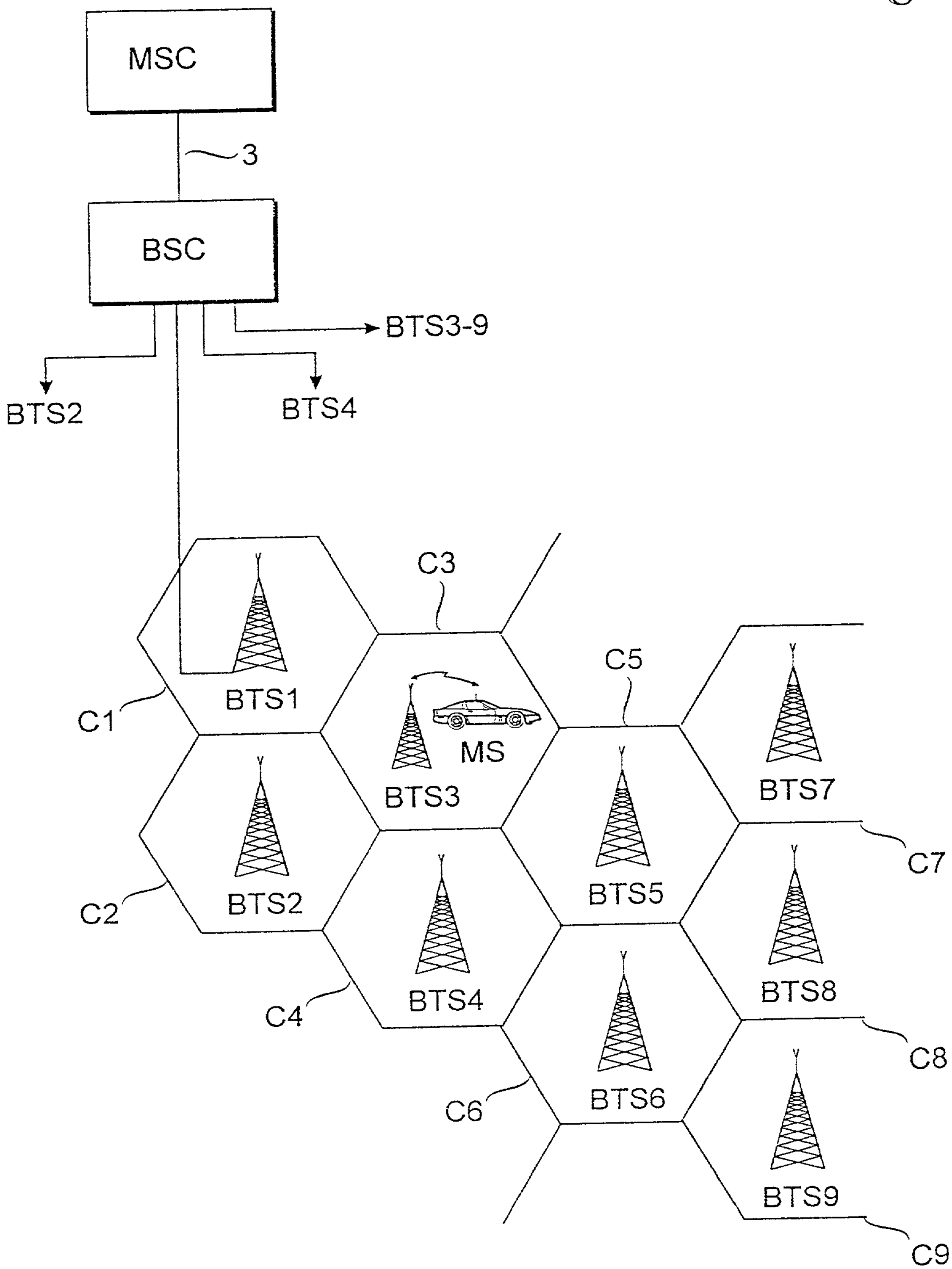
assigning at least one reference cell to at least one super-reuse frequency of the serving cell from among said ambient cells, said reference cell having an interference profile of a similar type as a more remote cell which is a potential source of interference on the super-reuse frequency but cannot be directly measured by the mobile station,

estimating the level of interference caused by said more remote cell on the super-reuse frequency, using the measured signal level of the reference cell.

15. A method as claimed in Claim 14, characterized by

correcting the measured signal level of the reference cell taking into account the difference in the signal levels of the reference cell and said remote cell in the estimation of the interference level.

Fig. 1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C5
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BTS3
BTS7
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C2
BTS5
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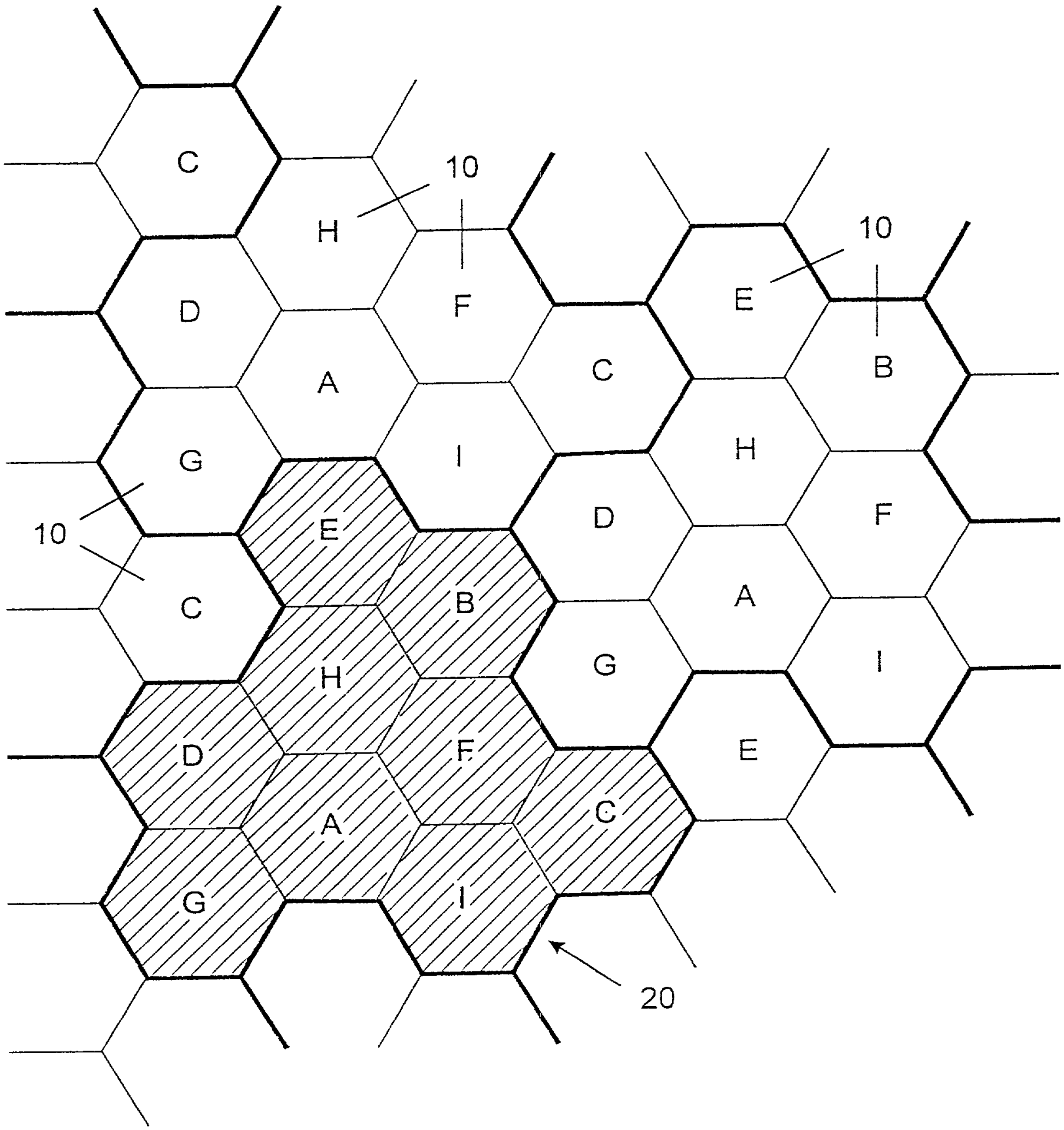
BTS8
C4
C8
C6
BTS6
BTS9
C9

Fig. 2



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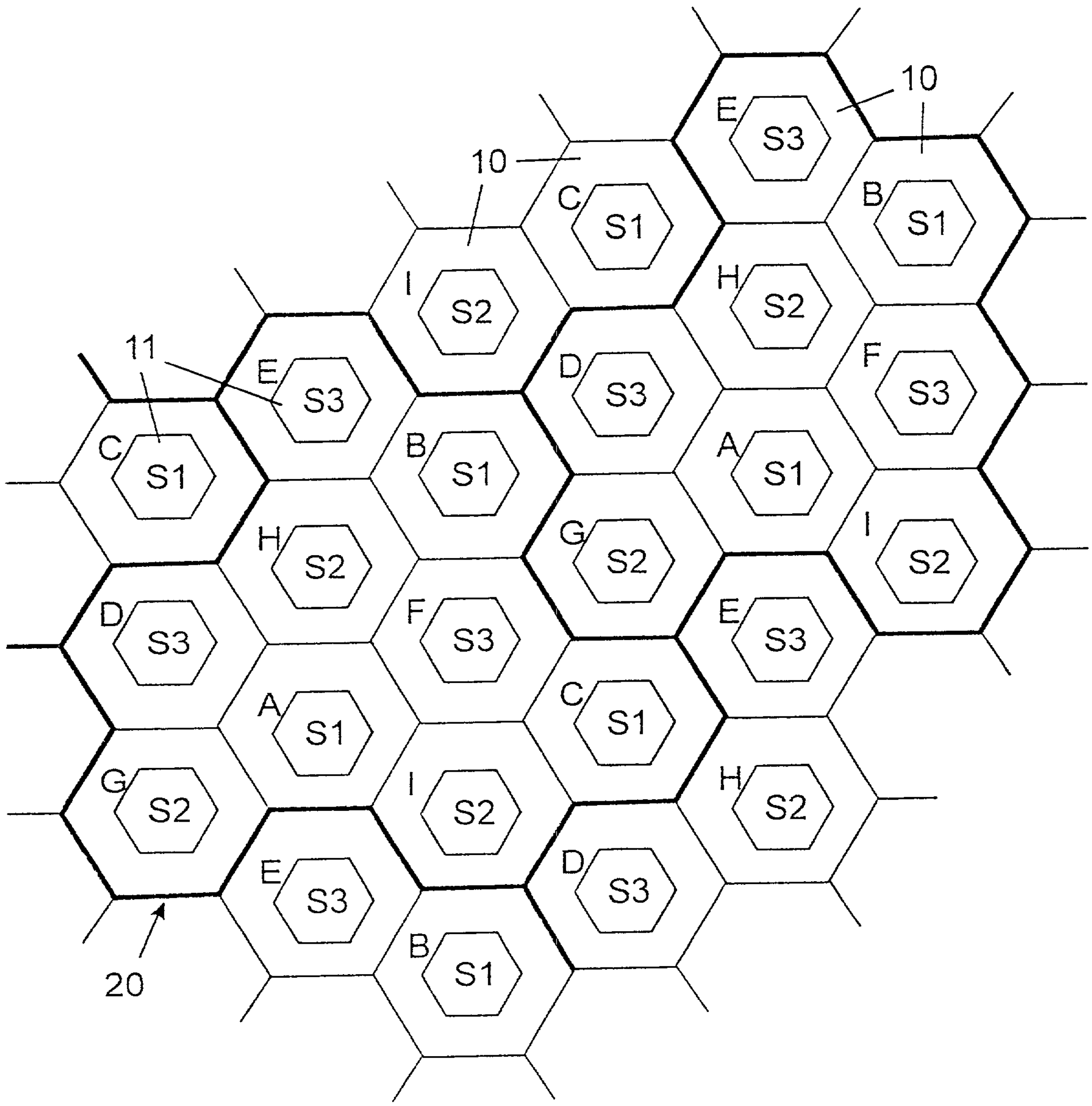
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H S2
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I S2
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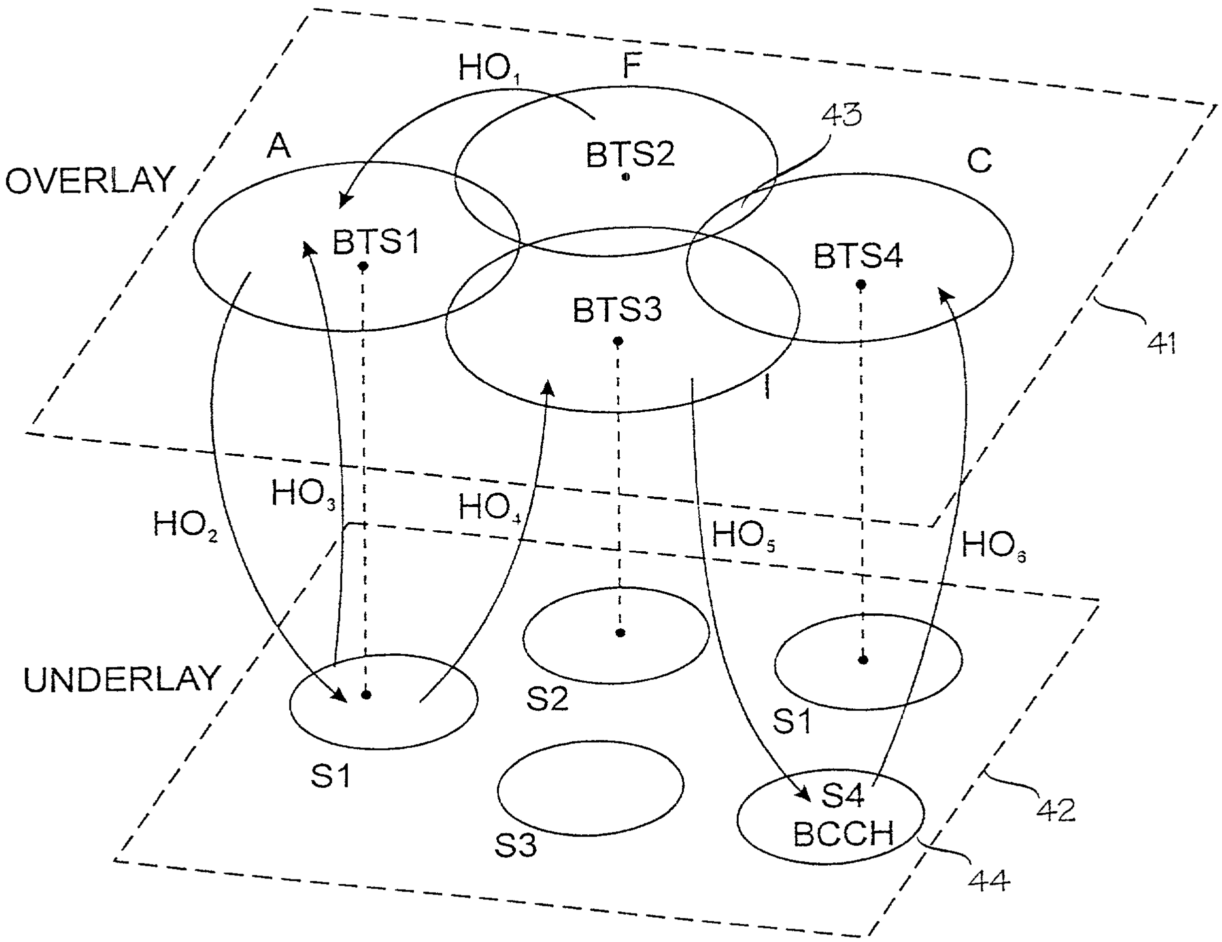
B S1

Fig. 4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A
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C
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BTS3
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I
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HO4
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UNDERLAY
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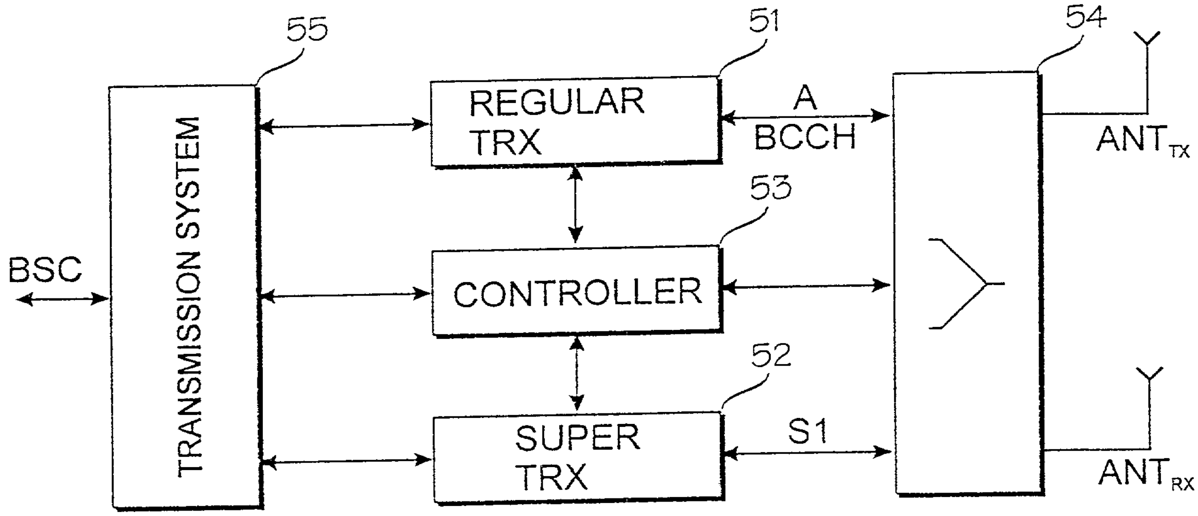
S1
S1
S4
BCCH
42
S3
44

Fig. 5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REGULAR TRX
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BCCH
ANT$_{TX}$
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BSC
TRANSMISSION SYSTEM
CONTROLLER
52
SUPER TRX
S1
ANT$_{RX}$

Fig. 6

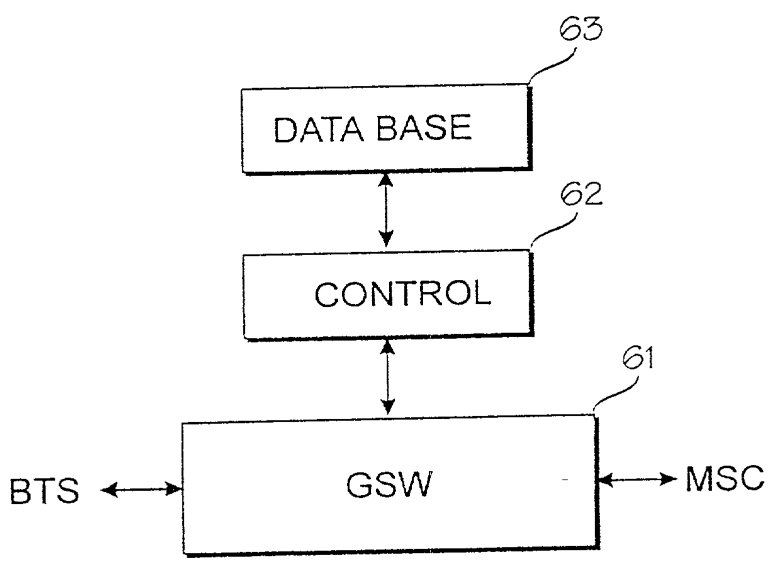
63
DATA BASE
62
CONTROL
61
BTS
GSW
MSC

Fig. 7

Base station	Handover threshold 1	TRX	TRX type	Interfering base stations
BTS1	SuperReuseGoodC_iThreshold Id (CiRatio, Nx, Px)	TRX1	REGULAR TRX	
	SuperReuseBadC_iThreshold Id (CiRatio, Nx, Px)	TRX2	SUPER-REUSE-TRX	BTS4 (LevelAdjustment,CIEstWeight, CIEstType) BTS9 (LevelAdjustment,CIEstWeight, CIEstType) ... ...
BTS2				

FOR UTILITY/DESIGN
CIP/PCT NATIONAL/PLANT
ORIGINAL/SUBSTITUTE/SUPPLEMENTAL
DECLARATIONS

RULE 63 (37 C.F.R. 1.63)
DECLARATION AND POWER OF ATTORNEY
FOR PATENT APPLICATION
IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

CUSHMAN
FORM

As a below named inventor, I hereby declare that my residence, post office address and citizenship are as stated below next to my name, and I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the INVENTION ENTITLED

Increasing the capacity of a cellular radio network

the specification of which (CHECK applicable BOX(ES))

-> [ ] is attached hereto.

X -> [ ] was filed on ______ as U.S. Application No. 0 / ______

BOX(ES) -> [X] was filed as PCT International Application No. PCT/FI96 / 00540 on 11 October 1996

-> -> and (if applicable to U.S. or PCT application) was amended on ______

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above. I acknowledge the duty to disclose all information known to me to be material to patentability as defined in 37 C.F.R. 1.56. I hereby claim foreign priority benefits under 35 U.S.C. 119/365 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate filed by me or my assignee disclosing the subject matter claimed in this application and having a filing date (1) before that of the application on which priority is claimed, or (2) if no priority claimed, before the filing date of this application:

PRIOR FOREIGN APPLICATION(S) Number	Country	Day/MONTH/Year Filed	Date first Laid-open or Published	Date Patented or Granted	Priority Claimed Yes	No
954879	Finland	13 October 1995			X	

I hereby claim domestic priority benefit under 35 U.S.C. 120/365 of the indicated United States applications listed below and PCT international applications listed above or below and, if this is a continuation-in-part (CIP) application, insofar as the subject matter disclosed and claimed in this application is in addition to that disclosed in such prior applications, I acknowledge the duty to disclose all information known to me to be material to patentability as defined in 37 C.F.R. 1.56 which became available between the filing date of each such prior application and the national or PCT international filing date of this application:

PRIOR U.S. PROVISIONAL, NONPROVISIONAL AND/OR PCT APPLICATION(S) Application No. (series code/serial no.)	Day/MONTH/Year Filed	Status pending, abandoned, patented	Priority Claimed Yes	No

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

And I hereby appoint Cushman Darby & Cushman Intellectual Property Group of Pillsbury Madison & Sutro LLP, 1100 New York Avenue, N.W., Ninth Floor, East Tower, Washington, D.C. 20005-3918, telephone number (202) 861-3000 (to whom all communications are to be directed), and the below-named persons (of the same address) individually and collectively my attorneys to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith and with the resulting patent, and I hereby authorize them to delete names/numbers below of persons no longer with their firm and to act and rely on instructions from and communicate directly with the person/assignee/attorney/firm/organization who/which first sends/sent this case to them and by whom/which I hereby declare that I have consented after full disclosure to be represented unless/until I instruct the above Firm and/or a below attorney in writing to the contrary.

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G. Lloyd Knight	17698	Donald J. Bird	25323	Paul E. White, Jr.	32011	James D. Berquist	34776
Carl G. Love	18781	W. Warren Taltavull	25647	Michelle N. Lester	32331	Timothy J. Klima	34852
Edgar H. Martin	20534	Peter W. Gowdey	25872	Jeffrey A. Simenauer	31993		
William K. West, Jr.	22057	Dale S. Lazar	28872			Stephen C. Glazier	31361
Kevin E. Joyce	20508	Glenn J. Perry	28458	G. Paul Edgell	24238	Paul F. McQuade	31542
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Residence (City) ______ (State/Foreign Country) ______
Post Office Address (Include Zip Code) ______

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Inventor's Name (typed) ______ First ______ Middle Initial ______ Family Name ______ Country of Citizenship ______
Residence (City) ______ (State/Foreign Country) ______
Post Office Address (Include Zip Code) ______

(FOR ADDITIONAL INVENTORS, check box [ ] and attach sheet (CDC-116.2) for same information for each re signature, name, date, citizenship, residence and address.)